XVI.—*Notes on the Structure of the* Crinoidea, Cystidea, *and* Blastoidea. By E. Billings, F.G.S., Palæontologist of the Geological Survey of Canada*.

[Continued from vol. v. p. 416.]

6. *On some points relating to the Structure of* Pentremites.

Professor Wyville Thomson has proposed a division of the skeleton of the existing Crinoid *Antedon rosaceus* into two systems of plates, which he terms respectively the "*radial*" and the "*perisomatic*" systems†. These he considers to be

Fig. 1. Fig. 2.

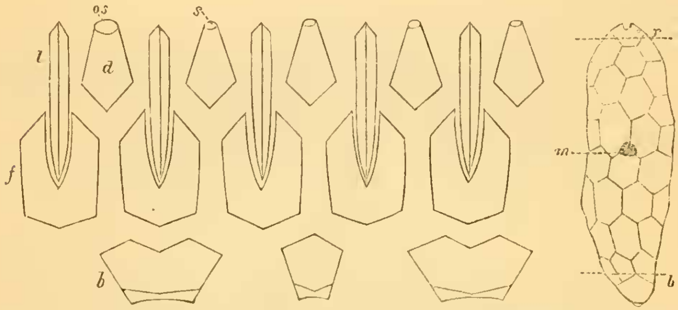

Fig. 1. Calycine plates of *Pentremites*: *b*, the basals; *f*, one of the five forked plates; *d*, deltoid plate; *l*, lancet-plate; *os*, oral spiracle; *s*, spiracle. Fig. 2. *Caryocystites testudinarius*, Hisinger: *b*, basal plates; *r*, radials; *m*, mouth.

thoroughly distinct from each other in their structure and mode of growth. The radial system consists of the joints of the stem, the centro-dorsal plate, the radial plates, the joints of the arms, and also those of the pinnules. In the perisomatic system he includes the basal and oral plates, the anal plate, the interradial plates, and any other plates or spicula which may be developed in the perisome of the cup or disk. This I think a good arrangement, except in so far as it regards the stem, which appears to me to be always an appendage of the perisomatic rather than of the radial system.

Throughout the whole range of the Crinoidea, the plates of the radial and perisomatic systems are easily distinguished from each other. In general the Cystidea have no radial plates in their calyces, except, perhaps, in a small area around

* From 'Silliman's American Journal of Science,' Sept. 1870.

† "On the Embryogeny of *Antedon rosaceus*, Linck (*Comatula rosacea* of Lamarck), by Professor Wyville Thomson, LL.D. &c." Philosophical Transactions of the Royal Society, vol. clv. part 2. p. 540.

the ambulacral orifice. This accords well with an important observation of Professor Thomson's on the structure of *Antedon* while in the earlier periods of its growth. "The entire body of the Pentacrinoid is," he says, "at first, while yet included within the pseudembryo and during its earliest fixed stage, surrounded and enclosed by plates of the perisomatic system alone; and it is quite conceivable that plates belonging to this system may expand and multiply so as to form a tessellated external skeleton to the mature animal, the radial system being entirely absent or represented only in the most rudimentary form" (*op. cit.* p. 541). Such is the structure of all the Cystidea. On referring to fig. 2, it will be seen that the whole of the body of *Caryocystites testudinarius* is covered with polygonal plates, without any trace whatever of a radiated arrangement. The plates are disposed in nine transverse ranges, girding the body like so many rings. This species is (and so are most of the elongated subcylindrical Cystideans) annulated rather than radiated, so far as regards the external integument. The lower range, below the line *b*, consists of the basals, whilst the upper, above the line *r*, may possibly be radiated. In all the globular or ovate Cystideans with numerous plates, such as *Sphæronites*, *Malocystites*, *Comarocystites*, *Amygdalocystites*, and others, the shell is neither annulated nor radiated, but composed of an indefinite number of plates, increasing with the age of the individual, and arranged without any well-defined or constant order. It seems clear, therefore, that the test of the Cystidea belongs mostly to the perisomatic system.

In *Pentremites* the three plates which are usually called the basals consist each of two pieces, one placed above the other, and in general closely anchylosed together. The lower pieces have each a re-entering angle in their upper edges, for the reception of the upper pieces which stand upon them. This structure was first pointed out by Mr. Lyon (Geol. Ky. vol. iii. p. 468), and is not generally admitted, although I believe it certainly does exist. It is said that the lower pieces consist of the upper joint of the column, divided into three by vertical sutures. To me they appear to be calycine plates. It is true that they do not form the bottom of the visceral cavity; but this may be due to the growth inward of the lower edges of those of the upper series. Something like this occurs in *Antedon*, where at first the bottom of the cup is formed by the basals, but afterwards principally by the first radials.

The forked plates are usually called "*radials*," but they certainly do not belong to the radial system. If they did, they would represent the first radials of the Crinoidea, and therefore they should support the bases of the ambulacra. A little consideration, however, will enable any one to perceive that in *Pentremites* the bases of the ambulacra are situated in the apex of the fossil, and do not come into contact with the forked plates. The apex of *Pentremites* is identical with the actinal centre of sea-urchins and starfishes, in which the mouth is situated. It is here that the ambulacra originate, and grow outward by the addition of new plates to their distal extremities. There can be little doubt that such was the mode of growth of the ambulacra of the *Pentremites*. The smaller extremity, therefore, of their ambulacra, which is received into the forked plate, is not the base, but corresponds with the apex of the ambulacrum of a sea-urchin or of a starfish. It also represents the tip of the arm of a Crinoid. If the forked plate is radial, then the arrangement of the ambulacrum must be the same as that which would be exhibited in a Crinoid with the upper end of the arm downward and resting on the first radial, whilst the lower end would be upward, the tip being formed of the second radial. From this it follows that the forked plates do not belong to the radial, but to the perisomatic system.

The five deltoid plates alternate with the forked plates, and are also perisomatic.

It is not certain that the lancet plates represent any of those plates which in the Crinoidea are usually called "radials." They are so arranged that if they were loosened from the walls of the cup, and their smaller extremities turned upward whilst their bases or larger ends retained their position, they would stand in a circle around the apex, as do the arms of an ordinary Crinoid. Their bases would alternate with the apices of the deltoid plates. They would form the outside of the arms, whilst the grooves and pinnulæ would be inside. Each would bear on its outer or dorsal aspect two elongated sacs, the two hydrospires that belong to the ambulacrum. I believe that the small groove in the ambulacrum of *Pentremites* was occupied by the ovarian tube only. If this be true, and if, also, the lancet plates represent the radial plates of the arms of the Crinoids, then the arm of *Pentremites* would have the respiratory portion of the ambulacral system on its dorsal, and the ovarian portion on its ventral aspect.

In the true Crinoids, both the respiratory and ovarian tubes are situated in the groove in the ventral side of the arm*. In

* Thomas Say, who was the first to recognize the Blastoidea as a group distinct from the Crinoidea, also supposed the function of the ambulacra to be respiratory. He says, "I think it highly probable that the branchial apparatus communicated with the surrounding fluid through the pores of the ambulacra by means of filamentous processes; these may

the Crinoids the pinnulæ are attached to the radial joints of the arm; in *Pentremites* they are not connected with the lancet plate, but with the pore-plates; in *P. pyriformis* they appear to me to stand in sockets excavated in the suture between the pore-plates proper and the supplementary pore-plates. Miller compared them to the series of azygos plates which underlie that portion of the ambulacrum of *Pentacrinus* that runs from the mouth to the base of the arm. These resemble the lancet plates in their being azygos and not connected with pinnulæ; but then, on the other hand, they differ from them in having a portion at least of the respiratory tubes on their ventral aspect. Mr. Rofe says that "in many species of *Pentremites*, if not in all, this lancet plate is in reality a compound plate, formed of two contiguous plates extending from the bottom of the sinus to the top, and then, turning right and left round the summit-openings, they pass down the adjoining sinus to form half its lancet plate, leaving at the apex of the body a pentagonal aperture supposed to be the mouth. In some weathered specimens the two parts of the lancet plate are separate; and in many they appear to meet only at the top and bottom of the cross section, leaving a lozenge-shaped opening between them" (Geol. Mag. vol. ii. p. 249). In a large specimen of *P. obesus* (Lyon and Cassiday), which was given to me by Mr. Lyon, a polished section shows that one of the lancet plates is thus divided; but in general no trace of a suture can be seen in these plates.

There are several points in the structure of the ambulacra of *Pentremites* that are well worthy of the study of those who have plenty of well-preserved specimens. Among these I would direct special attention to the markings in the ambulacrum of *P. pyriformis*. The median groove, which I suppose to have been exclusively occupied by the ovarian tubes, sends off branches, right and left alternately, toward the sides of the ambulacrum. These branches do not run directly to the ambulacral pores. Each of them terminates at a point between the inner extremities of two of the pores. There is at this point a small pit, which appears to be the socket of an appendage quite distinct from the pinnule. The groove does not reach the socket of the pinnule, which is situated further out,

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also have performed the office of tentacula in conveying food to the mouth, which was perhaps provided with an exsertile proboscis; or may we not rather suppose that the animal fed on the minute beings that abounded in the sea-water, and that it obtained them, in the manner of the Ascidia, by taking them in with the water? The residuum of digestion appears to have been rejected through the mouth." (Journ. Acad. N. S. Phil. 1825, vol. iv. p. 296.)

between two of the pores. On the other hand, a small groove runs from each pore inward, and terminates at another socket about halfway between the pore and the main median groove of the ambulacrum. It would thus appear that, besides the ordinary pinnules, there were two other rows of appendages on each side of the median groove.

The general conclusions at which I have arrived from the above are—that all the principal plates that compose the shell of *Pentremites* belong to the perisomatic system of Professor Wyville Thomson, that it is doubtful whether or not the lancet plates are homologous with the radial plates of the Crinoids, and that the ambulacra are more complicated in their structure than is generally supposed.

7. *On the Structure of the Genus* Nucleocrinus.

The body of this remarkable genus is ovate, elliptical, or oblong, and enclosed in a shell of strong perisomatic plates, which are in general so closely anchylosed that the sutures between

Fig. 3.

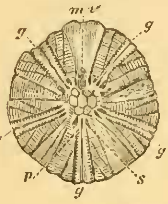


Fig. 4.

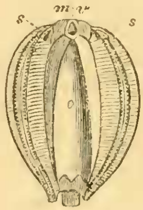


Fig. 5.

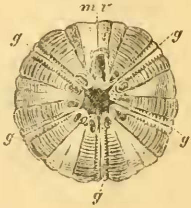


Fig. 6.

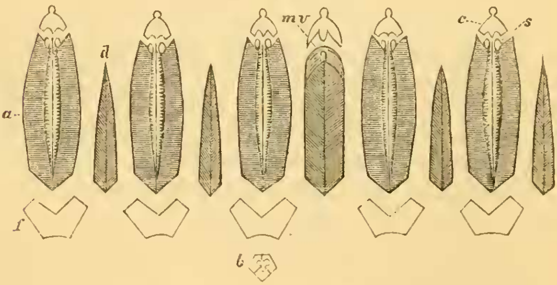


Fig. 3. Apex of *Nucleocrinus Verneuilii*, Troost: *g*, ambulacral groove; *p*, pore through which the groove enters into the interior; *s*, one of the ten spiracles; *mv*, oro-anal aperture. Fig. 4. Anterior side of a specimen: *o*, the anterior interradial. Fig. 5. Apex of a specimen which has lost the integument that covered the centre. Fig. 6. Diagrams of the plates of the test: *a*, ambulacral plate; *b*, the basals; *c*, plates of the apex; *d*, one of the interradials; *f*, forked plate.

them cannot be distinguished. According to Mr. Lyon, who, through his long-continued geological researches has collected and studied a vast number of specimens, there are three minute lozenge-shaped or quadrilateral basal plates, situated at the bottom of the columnal pit, always concealed when the column is present. These are surrounded by three other plates, the six together corresponding to the six pieces which constitute the compound basal plates of *Pentremites.* They are represented at fig. 6 *b*, as figured by Mr. Lyon (Geol. Ky. vol. iii. pl. 5. fig. 1 *b*).

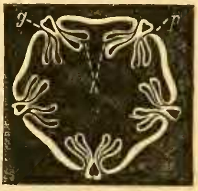
In the next series there are five plates, which are undoubtedly the homologues of the five forked plates of *Pentremites.* They are very short, and confined to the base of the body. They form a shallow basin with ten re-entering angles in its margin (fig. 6 *f*).

Alternating above the forked plates are five pieces corresponding to the deltoid or interradial plates of *Pentremites.* Some of these are lanceolate in form (fig. 6 *d*), their broader extremities fitting into the angles between the forked plates. They taper to a point upward; and their sides are bevelled so as to pass under the ambulacral plates, to which they are in general so closely united that the line of junction is indicated only by the difference in the markings of the surface. Owing to this structure, these plates have not always been recognized by the authors who have described this genus. They were first pointed out by Mr. Lyon. The fifth deltoid or interradial plate is truncated at its apex for the reception of the oro-anal orifice (*mv*, figs. 4, 6). The sutures on each side of this plate are generally distinctly visible, especially in the upper part of the body.

The ambulacra are narrow—one line wide in a specimen fifteen lines in length, with a fine median groove about large enough to accommodate a tube of the size of a horse-hair. There are two rows of pores, those on one side of the groove alternating in position with those on the other side. These pores lead into the hydrospires. There appear to be only two rows of ambulacral ossicles. The pores are situated in the sutures between them. On each side of the ambulacrum there is a broad, transversely grooved marginal plate. From each pore a small rounded ridge runs across this plate. The grooves between the ridges originate at the outer extremities of the ambulacral ossicles. In well-preserved specimens the surface of these marginal plates exhibits no other structure than the transverse grooves and ridges; but in one weathered specimen that I have examined they seem to be composed of a number of narrow elongated pieces arranged transversely in such a manner that two of them abut against the outer extremity of each of the ambulacral ossicles, and extend outward towards the interradials. This seems to prove that the marginal plates belong to the ambulacra, as pointed out by Mr. Lyon, and not to the interradials, as represented by other authors. Although I have studied a large number of specimens, none of them were sufficiently perfect to enable me to make out the whole structure of this part of the test of *Nucleocrinus*. I have, however, seen enough to convince me that the ambulacra are much more complex than is usually supposed. The lancet plate, if it occur at all in this genus, must be very narrow. The ambulacral groove, as in *Pentremites*, sends off branches right and left. There is also evidence of the existence of minute marginal plates on each side of the groove.

The hydrospires are ten elongated sacs, each with two deep folds. They are perfectly homologous with those of *Pentremites*, only differing therefrom in not being united in pairs; consequently there are ten spiracles instead of five. The mouth, or oro-anal orifice, is larger in proportion to the size size of the body than it is in *Pentremites*. Mr. Meek informs me that the mouth in some of the Blastoidea is protected by a single valve that covered it like the lid of a jug. From the structure of the orifice, I am inclined to think that in *Nucleocrinus* it possessed a similar protection.

Fig. 7.



[Fig. 7. Transverse section through a specimen which has all the hydrospires preserved: *h*, the two anterior hydrospires; *p*, pore leading into the hydrospire; *g*, one of the grooves.

In the apex nearly all the space within the circle of apertures is covered by a thin integument of small plates (fig. 3). When this is not preserved, a large subpentagonal aperture is seen, as shown in fig. 5. This aperture occupies the position of the mouth in the existing Echinoderms. The integument, as will be shown further on, represents that which covers the mouth of an embryonic starfish. Mr. Conrad described this genus, in 1842, as having only one aperture in the summit:— "This genus differs from *Pentremites*, Say, in having only one perforation at top, which is central" (Journ. Acad. Nat. Sci. Phil. vol. viii. p. 280, pl. 15. fig. 17). His figure represents the fossil with the apex downward. Dr. Ferd. Roemer showed that, when perfect, there is no central opening; and he made this one of the grounds for separating the genus from *Pentremites*. He described the apex as being provided with six apertures, five of which were divided by a partition within each: these he considered to be the ovarian orifices. The sixth he supposes to be both mouth and vent, which accords with my view (Mon. der Blastoideen, p. 378). In 1868 I discovered the five small pores at the apical extremities of the ambulacral grooves (Silliman's Amer. Journ. ser. 2. No. 97, p. 353, and Ann. Nat. Hist. ser. 4. vol. iv. p. 76). In general it is difficult to see these pores; but if a silicified specimen, which has been fossilized in a calcareous matrix, be placed in an acid for two or three minutes, the acid cleans them out, and they then become distinctly visible. I believe these to be the pores through which the ovarian tubes passed outward along the grooves to the pinnulæ. There are thus sixteen apertures in the apex of *Nucleocrinus*—ten spiracles, five ovarian orifices, and one oro-anal aperture. There are no true radial plates. The whole of the test, with the exception, perhaps, of the ambulacra, belongs to the perisomatic system.

8. *On the occurrence of Embryonic Forms among the Palæozoic Echinoderms.*

Fig. 8.

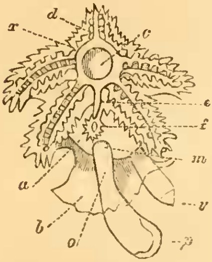


Fig. 9.

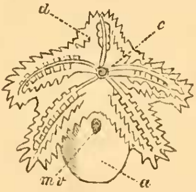


Fig. 10.

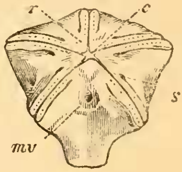


Fig. 11.

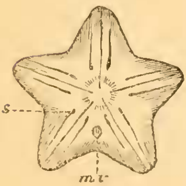


Fig. 8. *Bipinnaria asterigera*, Sars (copied from Müller): *a*, the stomach; *b*, part of the body of the larva; *c*, ambulacral centre, position of the permanent mouth, in this stage not open; *d*, one of the five ambulacral canals; *e*, sand-canal; *f*, madreporic plate; *m*, entrance into the stomach; *o*, œsophagus; *p*, larval mouth or pseudostome; *r*, œsophageal ring; *v*, vent. Fig. 9. Ideal figure described below. Fig. 10. *Codonites stelliformis*, oblique view, to show both body and summit. Fig. 11. Summit of fig. 10.

No proposition in natural history has been more clearly demonstrated than this—that in general the palæozoic animals resemble, both in external form and internal structure, the embryonic stages of those of the same class at present existing. Prof. Agassiz has long taught, in his lectures and various publications, that this is especially observable in the Echinodermata. Judging from the figures and descriptions of

Müller, Agassiz, Thomson, Carpenter, and others, I should say that in this class the most striking resemblance is that which occurs between the adult stages of the Cystidea, Blastoidea, and Crinoidea, on the one hand, and the embryonic starfishes on the other. The structural character that has the most important bearing on the subjects discussed in these notes is, that in all four of these groups the mouth is situated in one of the interradial areas, not in the ambulacral centre, as it is in the adult forms of the existing Echinodermata.

In *Bipinnaria asterigera*, Sars, according to Müller, the digestive cavity is a subglobular sac, without any extensions into the rays as there are in the adult starfishes. The œsophagus (fig. 8, *o*) is a fleshy, consistent tube, with a large mouth or pseudostome, *p*. It passes through the wall of the stomach by an opening somewhat smaller than the mouth, and situated in one of the interradial spaces at *m*. The madreporic plate (*f*) and the sand-canal (*e*), the latter holding the convoluted plate (when it occurs), are situated above the orifice (*m*), and between it and the ambulacral centre (*c*). The circular space at *c* is undoubtedly the homologue of the central space in the apex of *Nucleocrinus* (figs. 3 & 5) and of *Codonites* (figs. 10 & 11). It is also the position of the mouth in the adult starfish; but in the larval stage it is completely closed by the soft external skin and sarcode of the body. In the fossils it is also closed, but by an integument of thin calcareous plates. The *Bipinnaria* is nourished by minute particles of matter diffused through the water and drawn into the digestive sac through the mouth and œsophagus by the action of interradial cilia. I believe that all the fossil Crinoidea, Blastoidea, and Cystidea ingested their food in this way, and without any aid whatever from the arms or pinnulæ.

Perhaps there is no embryologist who will not admit that it is possible for an animal like *Bipinnaria* to develope organs of reproduction and propagate its species, none of its other parts making any further advance. Such an animal, with some slight modifications, would not be very widely different from a palæozoic Crinoid. If the sarcodic body-wall were to be consolidated into a thin calcareous integument, with the mouth even with the surface, the swimming-appendages aborted, and the vent closed up, it would resemble the cup of an *Actinocrinus* (fig. 9 *a*). The lateral orifice would then be both mouth and vent, as it is, at first (according to Prof. A. Agassiz, 'Sea-side Studies,' p. 125), in the embryo of *Asteracanthion berylinus*. The ambulacral canals of *Bipinnaria* are the homologues, in a general way, of those which are found beneath the vault of *Actinocrinus*, and extend outward into the grooves of the arms. If the ventral perisome of the Crinoid were to be removed (the internal organs remaining undisturbed) the arrangement disclosed would be that represented in fig. 9—a convoluted plate in the centre with the canals radiating from it. The most striking difference is the absence of the œsophageal ring. According to the organization of *Actinocrinus* there could be no œsophagus at that point; and consequently there is no ring. The convoluted plate represents the madreporic apparatus. The sucking-feet of the starfish most probably represent the respiratory tentacles that border the grooves of the Crinoids, but modified into prehensile and locomotive organs. *Bipinnaria* and *Actinocrinus* agree in having the mouth in one of the interradial areas, and in the absence of an orifice through the peristome at the ambulacral centre. These two characters are embryonic and transitory in the starfish, but they were permanent in most palæozoic Crinoids.

In *Codonites stelliformis* (*Pentremites stelliformis*, Owen and Shumard), figs. 10, 11, the ambulacral centre, *c*, is completely closed. Five minute grooves radiate to the extremities of the five angles of the disk. These grooves are identical with those of *Pentremites* and *Nucleocrinus* and were occupied by the ovarian tubes. The ambulacral canals of the true Crinoids and of the starfishes are represented in a rudimentary condition, in this species, by the hydrospires, which open out to the surface through the ten fissure-like spiracles (*s*). The oro-anal orifice is interradial. *C. stelliformis* in external form, the interradial position of the mouth, and the closed ambulacral centre resembles *Bipinnaria* and *Actinocrinus*, but differs importantly in having its respiratory organs arranged in ten separate tracts, all totally disconnected from each other. It is a lower form than *Actinocrinus*, which, in its turn, is lower than *Bipinnaria*; and yet all three are constructed on the same general plan.

C. stelliformis, although much resembling a *Pentremites*, is a true Cystidean. Its affinity to *Codaster* was first pointed out by Dr. C. A. White, who also suggested that it should be assigned to a distinct group (Bost. Journ. N. H. vol. vii. pp. 486, 487). The main difference between the Cystidea and the Blastoidea is, that in the former the hydrospires do not communicate with the pinnulæ, whilst in the latter the cavities of the pinnulæ and hydrospires are directly connected by the ambulacral pores.

The development of the recent Crinoid *Antedon rosaceus*, as described by Prof. Wyville Thomson (Phil. Trans. 1866), pursues a course that could not possibly result in the production of such an animal as *Actinocrinus*. The pseudembryo, as it is called by Prof. Thomson, is a small ovate organism, with four transverse ciliated bands, a large keyhole-shaped mouth (pseudostome), and a small circular vent (pseudoproct). These orifices are connected by a rudimentary intestine (pseudocele). In this stage there is no trace of radiation, and the mouth, therefore, cannot be said to be interradial in its position.

The nascent Crinoid originates within the pseudembryo, but developes a mouth, vent, and stomach of its own, all quite distinct from those of its nurse. This new or permanent mouth is for a short time both oral and anal in its function; but although in this respect it resembles that of *Actinocrinus*, its position in the centre of the ambulacral system shows it to represent the mouth of the adult starfish, while that of *Actinocrinus* homologizes rather with the oral orifice of the *Bipinnaria*. At no time during its development does the ventral perisome exhibit the structure of that of the palæocrinoids, *i. e.* no orifice in the ambulacral centre, and at the same time one in an interradial space. In the central position of its mouth, and in the possession of an œsophageal ring, *Antedon* stands above *Actinocrinus* in rank, and between it and the adult starfish. In none of its stages does it resemble a *Bipinnaria* either in form or in structure.

9. *On some of the Objections that have been advanced against the Views advocated in the preceding Notes.*

In all the known species of the existing Echinodermata the mouth is situated in the centre of the ambulacral system; and it is contended that this fact proves that such must have been its position also in the palæozoic forms.

This reasoning is not strictly logical. It is true that in the known existing species the mouth is in the centre; but it does not certainly follow that it is so in all the Echinodermata, living and extinct. Whether it is so or not in any particular fossil species whose structure may be under investigation, *is a question of fact which can only be positively determined by direct observation of specimens.* On appealing to these we find that, in a large proportion of the fossil forms, there is no aperture in the perisome at the ambulacral centre. It also becomes evident by the comparison that in general the palæozoic species resemble the embryonic stages of some of the recent Echinoderms, and that in these (*Bipinnaria* for instance) the mouth is interradial. Rules such as that relied on in this case, afford a certain amount of presumptive evidence, which, however, cannot prevail against material and visible facts. When we can see clearly that there is no aperture in that point in the vault of a Crinoid beneath which we know the ambulacral centre is situated, it is perfectly useless to supply one by deduction*.

The second objection is, that many of the fossils have a *Platyceras* attached to them in such a position as to cover the aperture which I call the mouth, and under such circumstances as to induce the belief that it lived parasitically on the Crinoid. The only answer I can make to this is, that, admitting the facts, we must suppose that space was left for a stream of water to pass under the edge of the shell into the mouth of the Crinoid. In general, where one animal lives parasitically upon another, it does not destroy its host. Some of the Gasteropods of the Devonian and Carboniferous ages were carnivorous, as is proved by the bored shells and Crinoids that are occasionally found. I have seen a number of such specimens, and several years ago I read a paper on the subject (which was never published) before the Natural-History Society of Montreal. There were several good conchologists present; and the specimens exhibited were compared with bored shells of existing species: all pronounced the style of workmanship to be precisely the same. I have the proboscis of an *Actinocrinus* that is bored near the base; and among the fossils lent me by Mr. Wachsmuth is a *Codonites stelliformis* that has one of the ambulacra bored through. The view I took of the subject in my paper was, that the Gasteropod ascended the stalk of the Crinoid and thrust its proboscis into the mouth of the latter. The Crinoid then slowly drew its arms together, and held the shell fast until both died.

Fig. 12.

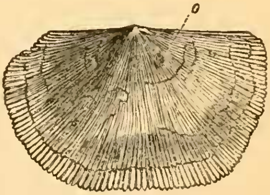


Fig. 12. *Streptorhynchus pandora*. A specimen bored at *o* by a carnivorous gasteropod. From the Corniferous Limestone, Devonian, Canada.

A third objection is the small size of the aperture in some of the species. In general, where there is no proboscis, the orifice is from one twentieth to one tenth of an inch in diameter, quite sufficient for an animal that subsists on micro-

* The position of the ambulacral centre may thus be found. When the mouth is eccentric, the ambulacral tubes usually converge to the centre of the vault; but when the mouth is central, we first find the azygos interradius, in general easily recognized by its possessing a greater number of plates than any one of the other four interradii. On the opposite side of the fossil is the azygos arm. The ambulacral centre is always situated between this arm and the mouth, never on the side of the mouth towards the azygos interradius.

scopic organisms. It is stated by Meek and Worthen that where there is a proboscis the aperture is sometimes scarcely "more than *one hundredth* of an inch in diameter." I believe that in many such instances the tube filled up by calcareous deposits on its inside, and that, when entirely obstructed, either a new aperture opened out in the side of the proboscis, or the animal died. In Mr. Wachsmuth's collection I saw a specimen with a second aperture in process of formation. A ticket was attached to it by him, giving this explanation. I am also informed that in some of the existing species of *Antedon* "the mouth is an exceedingly minute aperture."

A fourth objection is that the aperture is so situated that the arms could not have conveyed food to it. It is, however, proved by Dr. W. B. Carpenter that in the recent Crinoids the arms are not prehensile organs. The animal while feeding remains motionless, attached by its dorsal cirrhi to a stone, shell, or other object on the bottom. Its arms are either stretched out to their full length, or more or less coiled up, but quite immovable. As Dr. Carpenter's remarks have a very important bearing upon the subject, I shall take the liberty of quoting the following:—

"Whatever may be the purpose of the habitual expansion of the arms, I feel quite justified in asserting that it is *not* (as stated by several authors whom I have cited in my historical summary) the prehension of food. I have continually watched the results of the contact of small animals (as Annelids, or Entomostracan and other small Crustacea) with the arms, and have never yet seen the smallest attempt on the part of the animal to seize them as prey. Moreover the tubular tentacula with which the arms are so abundantly furnished have not in the slightest degree that adhesive power which is possessed by the 'feet' of the Echinida and Asteriada; so that they are quite incapable of assisting in the act of prehension, which must be accomplished, if at all, either by the coiling-up of a single arm, or by the folding-together of all the arms. Now I have never seen such coiling-up of an arm as could bring an object that might be included in it into the near neighbourhood of the mouth; nor have I seen the contact of small animals with a single arm produce any movement of other arms towards the spot, such as takes place in the prehensile apparatus of other animals. Moreover any object that could be grasped either by the coiling of one arm, or by the consentaneous closure of all the arms together upon it, must be far too large to be received into the mouth, which is of small size, and is not distensible like that of the Asteriada"*.

* "Researches on the Structure, Physiology, and Development of *Antedon* (*Comatula*, Lamk.) *rosaceus*." Part I. By W. B. Carpenter, M.D., F.R.S. (Philosophical Transactions of the Royal Society, vol. clvi. part 2, 1866. p. 699.)

Further on Dr. Carpenter says:—

"It was affirmed by M. Dujardin (L'Institut, No. 119, p. 268) that the arms are used for the acquisition of food in a manner altogether dissimilar to ordinary prehension; for, recognizing the fact that the alimentary particles must be of small size, he supposed that any such, falling on the ambulacral (?) furrows of the arms or pinnæ, are transmitted downwards along those furrows to the mouth wherein they all terminate, by the mechanical action of the digitate papillæ which fringe their borders. This doctrine he appears to have abandoned, since, in his last account of this type (Hist. Nat. des Echinodermes, p. 194), he affirms that the transmission of alimentary particles along the ambulacral (?) furrows is the result of the action of cilia with which their surface is clothed. Although I have not myself succeeded in distinguishing cilia on the surface which forms the floor of these furrows, yet I have distinctly seen such a rapid passage of minute particles along their groove as I could not account for in any other mode, and am therefore disposed to believe in their existence. *Such a powerful indraught, moreover, must be produced about the region of the mouth, by the action of the large cilia which (as I shall hereafter describe) fringe various parts of the internal wall of the alimentary canal, as would materially aid in the transmission of minute particles along those portions of the ambulacral* (?) *furrows which immediately lead towards it*; and it is, I feel satisfied, by the conjoint agency of these two moving powers that the alimentation of *Antedon* is ordinarily effected. In the very numerous specimens from Arran the contents of whose digestive cavity I have examined, I have never found any other than microscopic organisms; and the abundance of the horny rays of *Peridinium tripos* (Ehr.) has made it evident that in this locality that Infusorium was one of the principal articles of its food. But in Antedons from other localities I have found a more miscellaneous assemblage of alimentary particles, the most common recognizable forms being the horny casings of Entomostraca or of the larvæ of higher Crustacea." (*Op. cit.* p. 700.)

The existence of large cilia within the intestinal canal, capable of producing a powerful indraught of water, renders any movement or concurrent action of the arms quite unnecessary in the ingestion of food. It does not matter, therefore, in what part of the body the mouth of a Crinoid may be situated, or how remote from the reach of the arms. Attached permanently to the bottom of the sea by their columns, the palæozoic Crinoidea, Cystidea, and Blastoidea remained, while feeding, most probably motionless, drawing in streams of water through their mouths by the action of their intestinal cilia. The long tubular proboscis with which many of the species are provided would thus be analogous in function to the siphon of the Acephalous Mollusca. The indigestible particles would be, from time to time, thrown out through the mouth, just as a starfish or a zoophyte frees itself of the refuse portions of its food, by casting it out of the same aperture through which it entered.

10. *On the Theory that the Ambulacral and Ovarian Orifices are the Oral Apertures.*

Assuming that the four objections above noticed are sufficient to prove that the aperture which I call the mouth is not that organ, it is contended that the Cystidea, Blastoidea, and Palæocrinoidea ingested their food through their ambulacral and ovarian orifices. This appears to me in the highest degree improbable. In the recent Crinoids the grooves of the arms are occupied by four sets of tubes, which Dr. Carpenter calls the cœliac, the subtentacular, the ovarian, and the tentacular canals. None of them communicate with the stomach. It is impossible that the most minute particle of food could gain access to the interior of the animal through any of them. The structure of the arms of the palæozoic Crinoids is such that we must presume that their grooves were occupied by similar tubes, which passed through the ambulacral orifices into the perivisceral space. In the Cystidea and Blastoidea the respiratory organs were not situated in the grooves of the arms, and the ambulacral orifices were therefore only ovarian in their function. The improbability of their being also oral apertures is best shown by an illustration.

In fig. 13 is represented (natural size) the apertures of the smallest specimen of *Caryocrinus ornatus* in our collection, selected for the present purpose because in the young of this species the valvular orifice is larger in proportion to the size of the disk than it is in the adult. It is in this specimen about one third of the whole width of the apical disk, while in a full-grown *Caryocrinus* it is only one ninth of the width. The same proportional size of the mouth according to age occurs in *Antedon rosaceus*. The valvular mouth at first is as wide as the disk; but as the age of the animal increases, the disk grows wider, but the mouth does not. The ovarian pores in *Caryocrinus*, however, are as large in the small ones (once they make their appearance) as they are in those full-grown. For recognizing these as ovarian pores we have the following reasons:—1, they are situated at the bases of the arms where the ovarian tubes must pass from the grooves into the perivisceral cavity; 2, when compared with the ovarian pores of a sea-urchin, they have the same size, form, and aspect. Fig. 14 represents the ovarian pores of the sea-urchin *Toxo-*

Fig. 13.

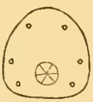
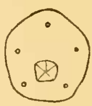


Fig. 14.



pneustes drobachiensis, Ag., natural size and arrangement. It may not appear at first view that this latter comparison has any probative effect. But it has, in this way. If these apertures in *Caryocrinus* were large openings a line wide, as are some of the ambulacral orifices of the Crinoids, I should say that they were unlike true ovarian apertures.

According to the new theory, this Echinoderm, *Caryocrinus ornatus*, was a polystome animal, and drew in its food through its six ovarian apertures, the large valvular orifice being the anus. To me this appears to be utterly incredible.

In fig. 14 I have represented the mouth of *Leskia mirabilis*, Gray. Both Dr. J. E. Gray and Prof. Lovén have pronounced this aperture to have the structure of the valvular orifice of the Cystidea. I have not the slightest doubt whatever that the mouth of the Cystideans foreshadows that of the sea-urchins. There is nothing whatever in its structure to show that it is not the mouth, but the contrary.

The new theory is not founded upon any peculiarities in the structure of the ambulacral orifices which would show that they are oral apertures, but only upon the four objections above noticed. The first of these is not logical, while at the same time it is purely theoretical, and avails nothing against material and visible facts. The fourth is completely disposed of by Dr. Carpenter's observations, which prove that in the Crinoidea the arms have no share whatever in the ingestion of food. The second and third objections are the same in substance; *i. e.* according to the second the supply of water to the mouth is diminished by the occurrenee of a *Platyceras* over it, while, according to the third, the same effect is produced by the small size of the aperture itself in some instances. It does not require much consideration to convince one that, if these two objections are fatal to my views, they are equally so to the opposite theory. In *C. stelliformis*, for instance, the pores through which we must suppose the ovarian tubes issued from the interior are only large enough to admit of the passage of a fine hair; they are scarcely visible to the naked eye. The tube, under any circumstances, must have filled them almost entirely. If any space at all were left for the passage of a stream of water through the pore by the side of the tube, it must have been exceedingly minute.

When weighed as above, therefore, the evidence gives the following results:—The first and fourth objections avail nothing; the second and third militate against both theories; but when we take into account that in no instance, in the existing Echinodermata, where ovarian pores occur, are they at the same time oral orifices, the balance seems to be in favour of my view. This is all I desire to say upon the subject at present. Although I now firmly believe that the valvular orifice in the Cystidea, the larger lateral aperture of the Blastoidea, and the so-called proboscis of the palæozoic Crinoids are all oro-anal in function, yet I shall not maintain that view obstinately against good reasons shown to the contrary.

XVII.—*On a Species of Arenaceous Foraminifer* (?) *from the Carboniferous Limestone of Devonshire.* By Edward Parfitt, Esq.

[Plate XI. figs. 9–12.]

To the Editors of the Annals and Magazine of Natural History.

Gentlemen,

I beg to enclose you a rough sketch of what I had at first regarded as a species of *Cliona* new to science; but on a more extended acquaintance with the specimens, and comparing them with the beautiful figures of the arenaceous Foraminifera described by Dr. Carpenter in the Royal Society's 'Transactions,' vol. clix. part 2, plates 72–76, I am now more inclined to regard it as a sessile arenaceous Foraminifer. This species or form I met with on a block of carboniferous limestone brought from the quarry of Westleigh, near Tiverton, Devonshire. The specimen covered a space of eight or ten inches, and was so consolidated with the rock that, had it not been for the weathered surface, I should have passed it by.

The weathered surface has just the appearance of what we might expect to see in a free fossil *Cliona*; the resupinate stolons, variously branched and attached, quite resemble those of the recent forms of this genus (fig. 9). On having a small specimen cut and polished, I was much surprised to find that all the interstices between the stolons were filled with sand, charged more or less with a ferruginous tint; and on applying nitric acid to the surface for some time, this ate away the calcareous portions and left the interstices standing up prominently between the calcareous disks. The sand, as now exposed, appears to be quartz; and, generally speaking, the grains are as sharply angular as if it had just been broken up on purpose for this animal, and used by it directly. On comparing the part which had been submitted to the acid with the figures in the Royal Society's 'Transactions,' pl. 76, there is a very strong family likeness at once apparent. In my specimen the labyrinthiform spaces are filled with calcareous matter of the same colour as, and apparently very little different from, the limestone; at the same time each of the spaces of the